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(71) Applicant
Brian Edwards
78 Chancellor Street, Glasgow, United Kingdom

(72) Inventor
Brian Edwards

(74) Agent and/or Address for Service
Brian Edwards
78 Chancellor Street, Glasgow, United Kingdom

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G06F 3/00

(52) UK CL (Edition J)
G4A AKS
F2Y YTA Y3309

(56) Documents cited
Proc of the International Conference on Cybernetics and Society, Nov 78, Tokyo-Kyoto, pp1298-1300
IEEE Transactions on Bio-Medical Engineering (USA), Vol BME-18 no 6 Nov 1971 pp389-398
Proc of the 3rd Hawaii International Conference on System Sciences Jan 1970 pp632-634

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INT CL⁴ G06F
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(54) Brain-wave-controlled computer interface

(57) A Brain Wave Controlled Computer Interface enables an individual to communicate messages to a computer by means of that individual's cerebral electrical activity. It usually comprises amplifier and filtering stage 1, a filter stage 2, comprised of N substages respectively tuned to suitable frequencies, an analogue to digital conversion stage 3, which can be comprised of N substages, and where appropriate an output and buffering stage 4.

The system user deliberately controls the electrical activity in his or her brain in a manner that can be detected by the Interface. This is a learned ability acquired through practice with appropriate bio-feedback aids.

In essence the cerebral electrical activity is varied in relative intensity at appropriate frequencies by the system user and these frequency signals are converted into a digital form that can be read by a computer or microprocessor based device.

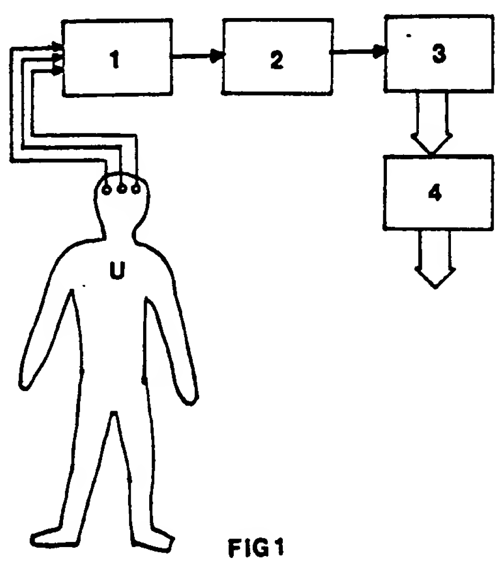

FIG 1

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This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1982.

B.C. Original

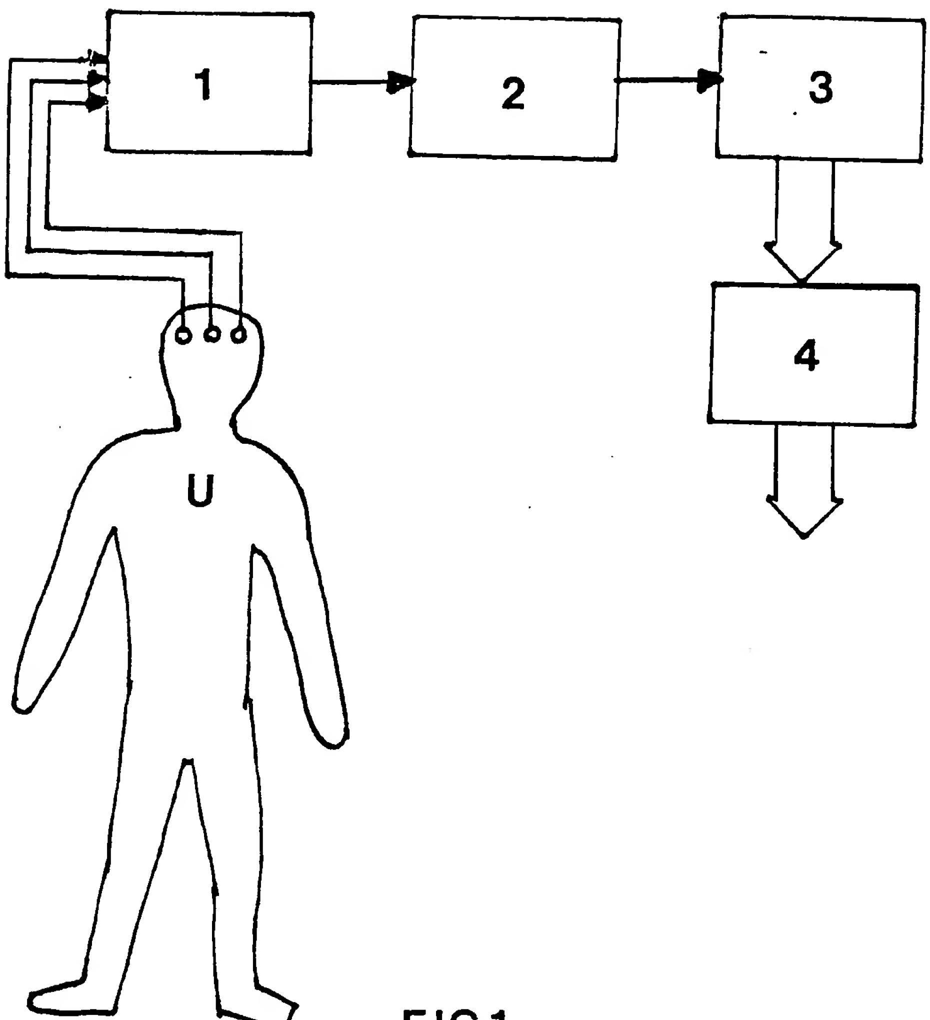

FIG 1

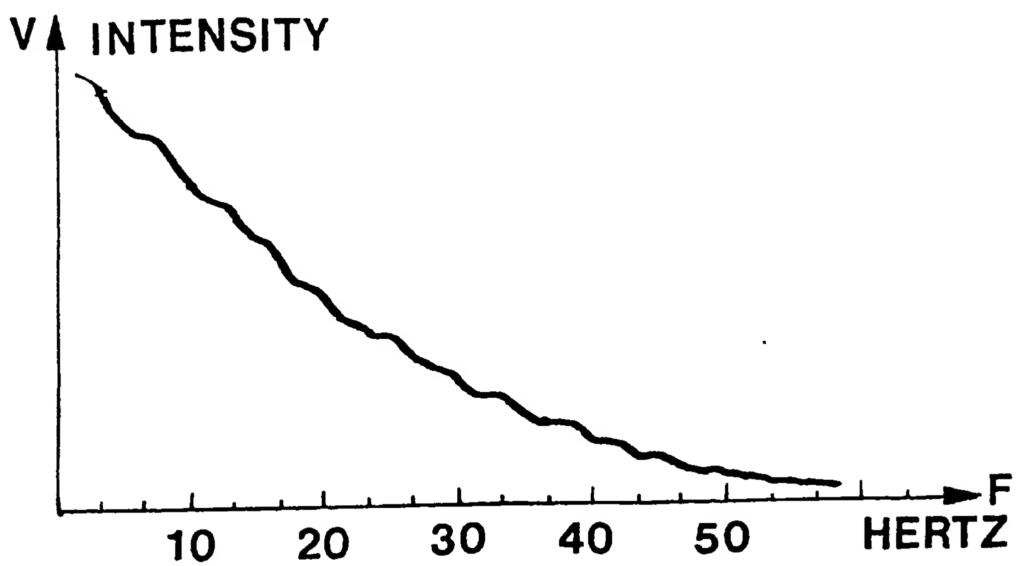

FIG 2

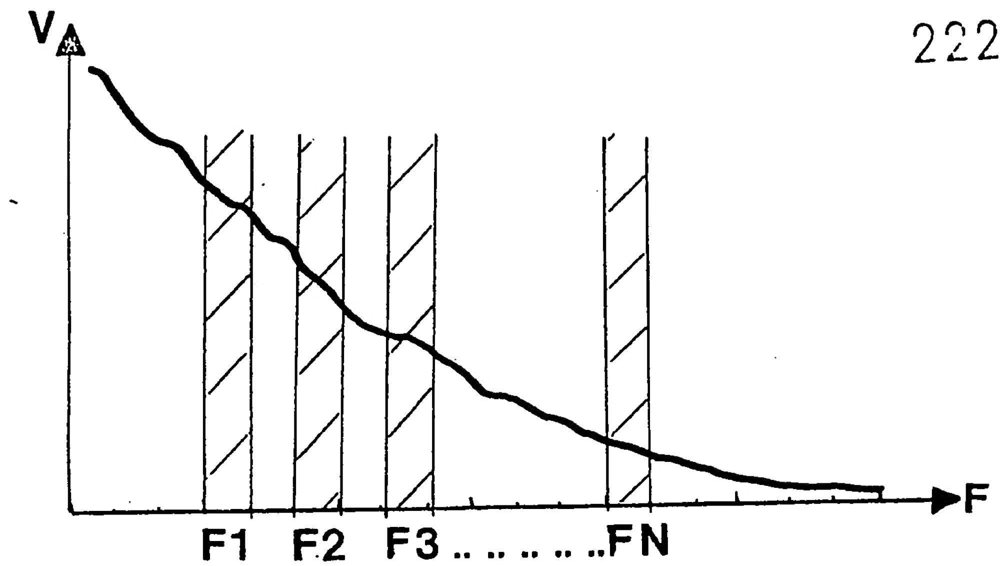

FIG 3

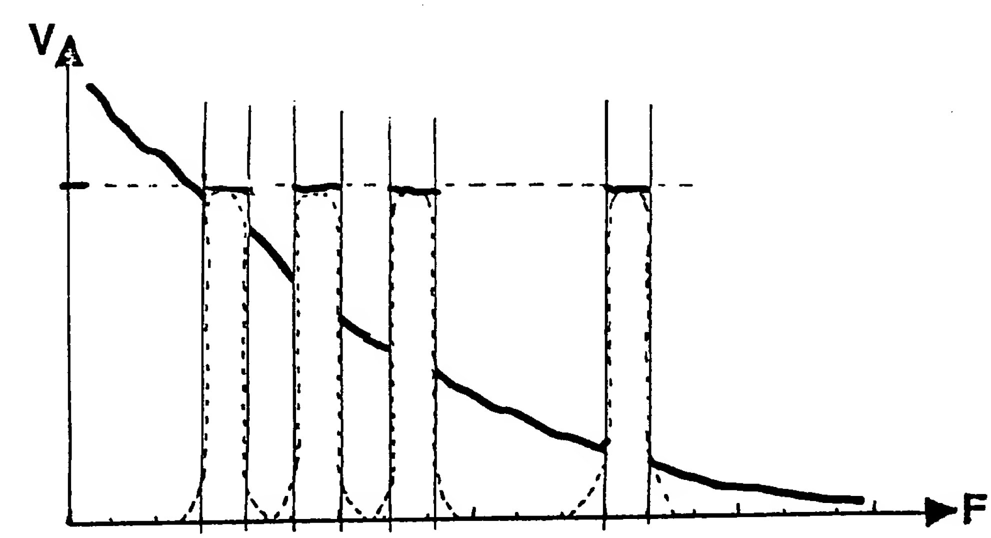

FIG 4

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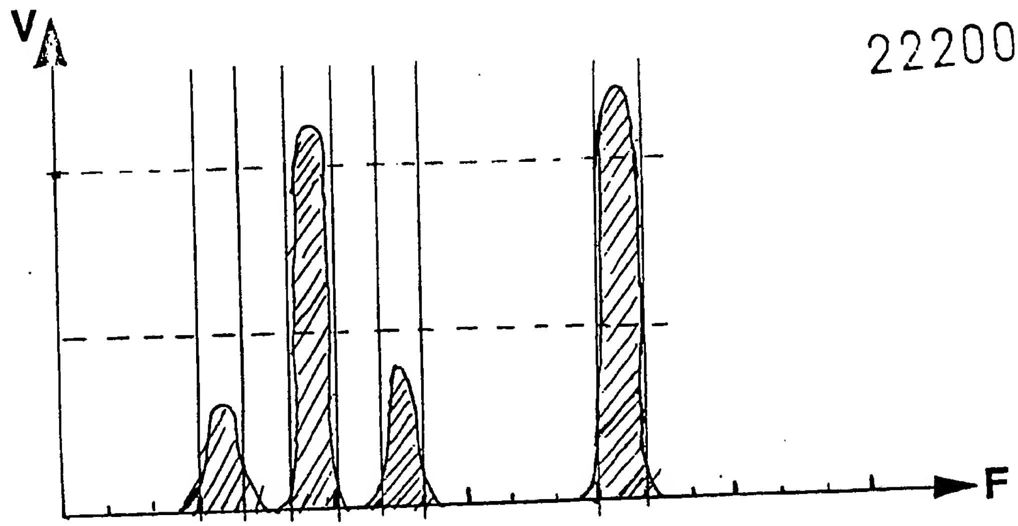

FIG 5

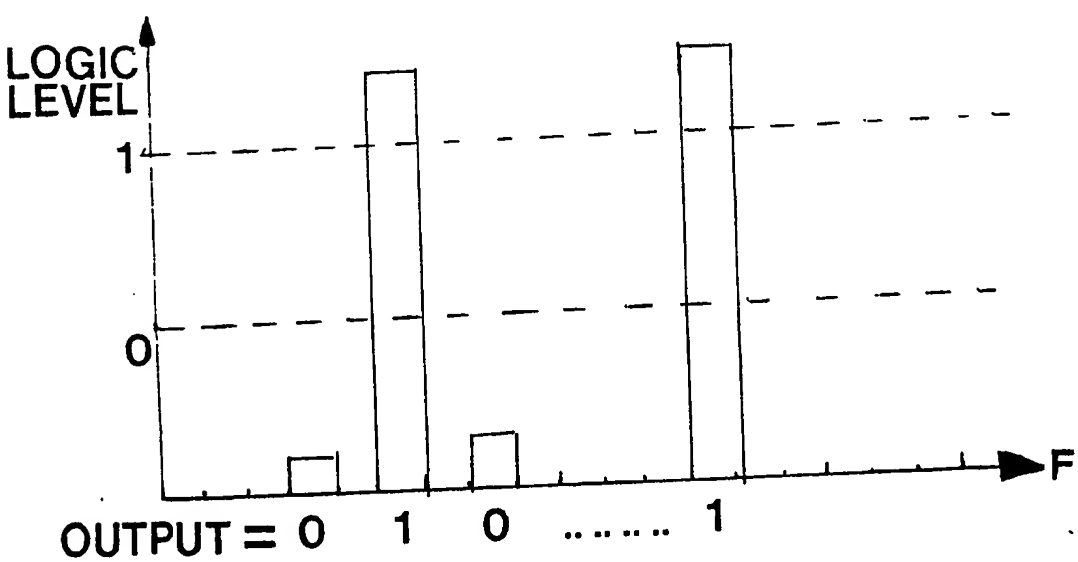

FIG 6

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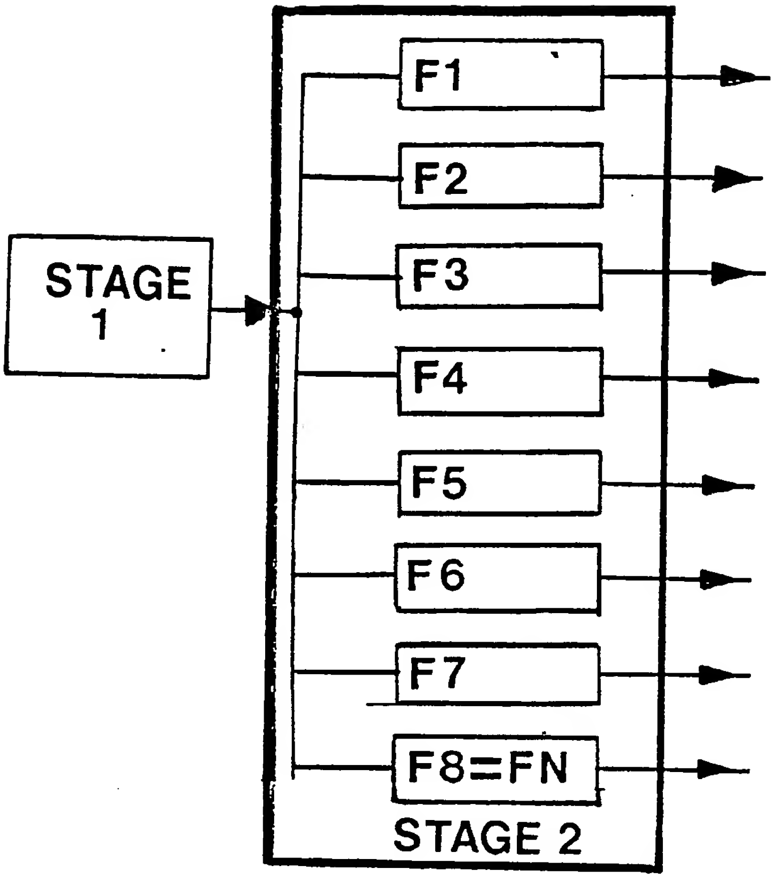

FIG 7

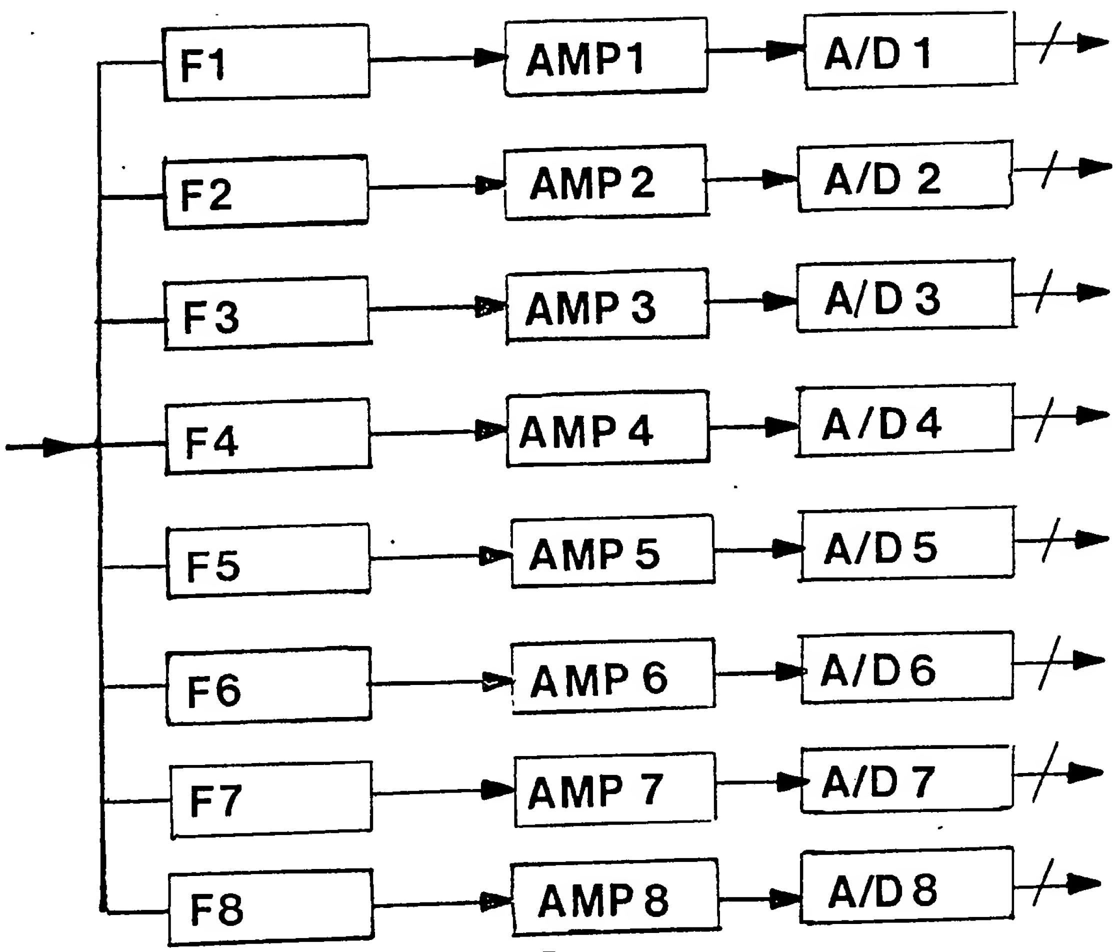
F1
F2
F3
F4
F5
F6
F7
F8
AMP1
AMP 2
AMP 3
AMP 4
AMP 5
AMP 6
AMP 7
AMP 8
A/D 1
A/D 2
A/D 3
A/D 4
A/D 5
A/D 6
A/D 7
A/D 8

FIG 8

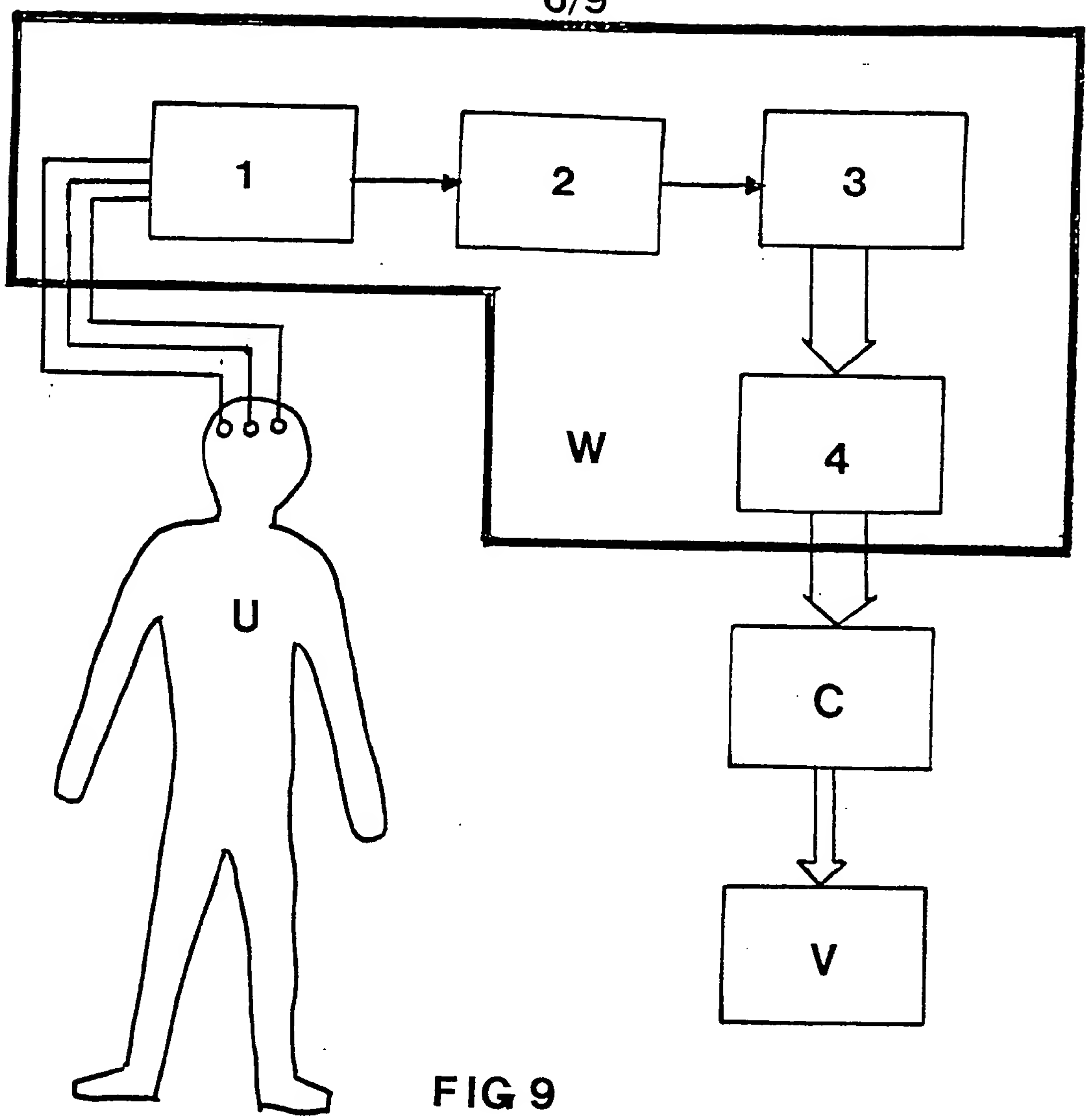

FIG 9

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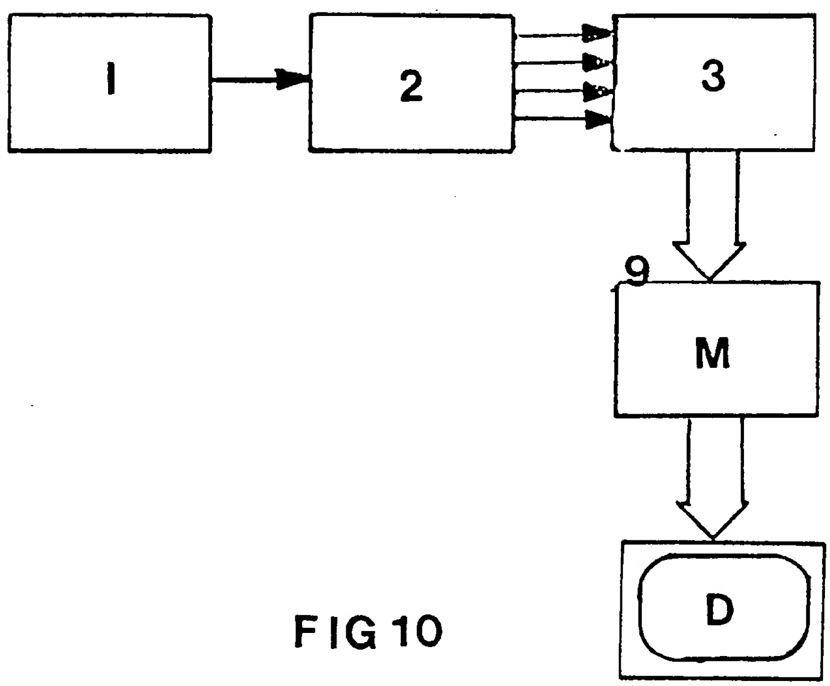

FIG 10

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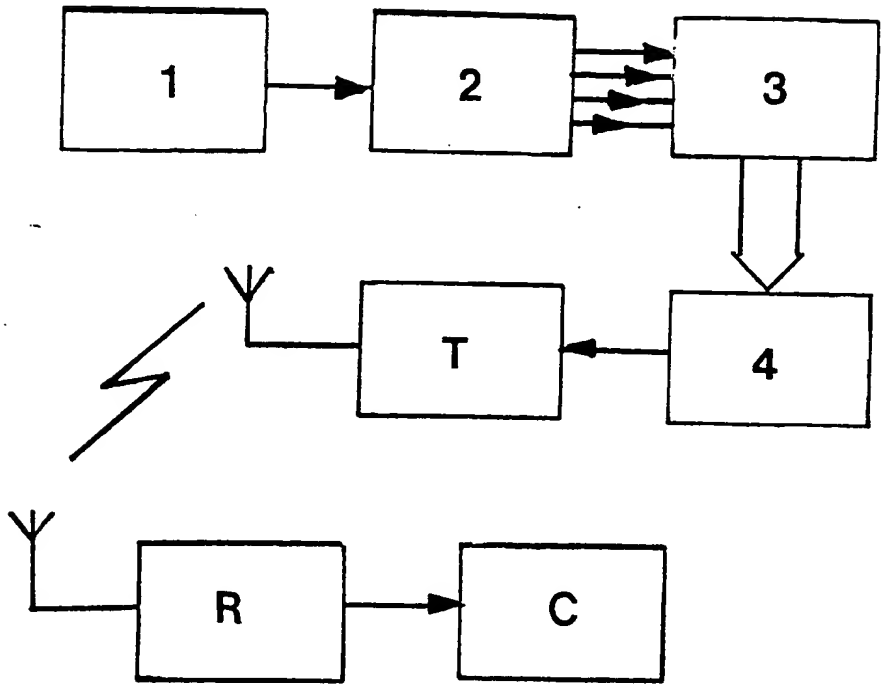

FIG 11

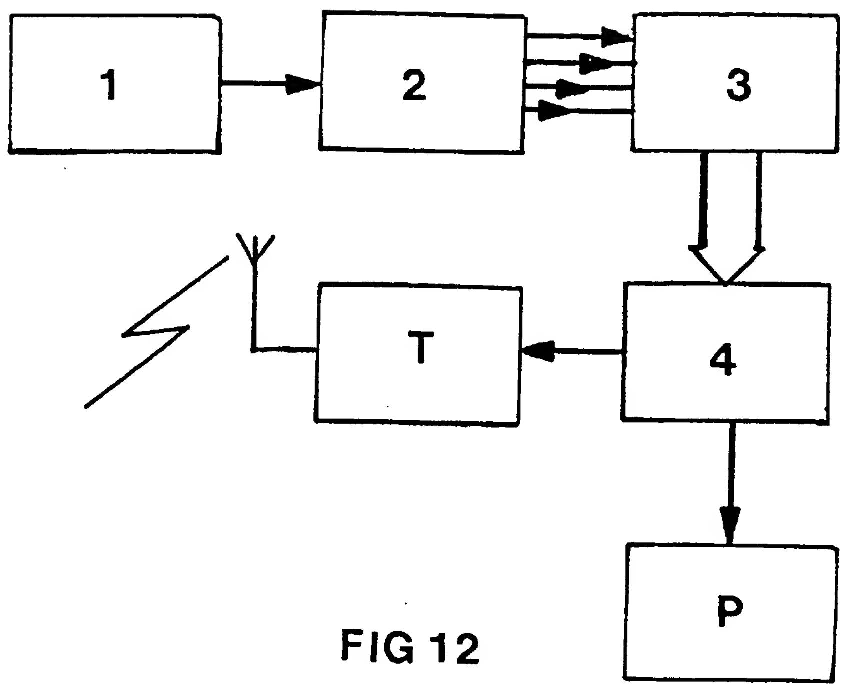

FIG 12

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Brain Wave Controlled Computer Interface

This invention relates to a brain wave controlled computer interface.

It is possible to build an electronic computer interface device that can be controlled by the electrical activity in the brain thus eliminating the need for a computer keyboard.

Frequency displays of cerebral electrical activity recorded with electrodes placed on the heads of alert normal individuals show continuous spectra of frequencies starting well below 1Hz and gradually falling off in intensity to become very small beyond 40 Hz to 50 Hz. It is this electrical activity that can be controlled to send out commands to computers or microprocessor controlled devices.

It is a well established fact that it is possible to modify brain wave patterns (or cerebral electrical activity) through bio-feedback techniques such as watching one's alpha and beta waves on an oscilloscope screen and seeking to modify them. This learned ability to control one's brain wave patterns (or cerebral electrical activity) is the means by which information can be fed into a computer.

According to the present invention there is a brain wave controlled computer interface device comprising sensors to input cerebral electrical information to stage one of the device. Stage one of the device is an amplifying and filtering stage feeding signals to stage two of the device which is a frequency filtering and splitting stage. It in turn feeds signals to stage three of the device, which is an analogue to digital conversion stage, which feeds signals out to a buffering and isolation stage, which is stage four of the device.

The present invention essentially consists first of electrodes or sensors that can be attached to the head, and these sensors feed electrical signals into amplifiers and filtering circuits similar to those used in normal EEG machines, then a set of active filter

stages to pick out individual frequencies that can be controlled by the system user. Then the outputs of these filter stages are each fed into analogue to digital conversion stages to convert the information into a form suitable for processing by a computer or by a microprocessor controlled device.

The actual ability used to communicate with the computer or microprocessor controlled device is the ability to alter the relative intensities of the norman continuous spectra of frequencies that constitutes the usual cerebral electrical activity of alert normal individuals. This electrical activity is altered in such a way that deliberately chosen variations on the normal intensity spectrum for an individual can be defined, with the aid of a computer or microprocessor controlled device, to correspond to units of communication such as alphanumeric characters, words, or phrases, or commands to a device.

Four specific embodiments of the invention will now be described by way of example with reference to the accompanying drawing in which:-

Figure 1 - shows a block diagram of the main stages of the device

Figure 2 - shows the cerebral frequency spectrum of a normal alert adult;

Figure 3 - shows the cerebral frequency spectrum of a normal alert adult with filter pass bands F1 to FN superimposed;

Figure 4 - of the drawing shows the same graph as before, but with the usual fall off in intensity with increasing frequency compensated for in the regions of the pass bands;

Figure 5 - of the drawing shows the effect of varying some brain wave frequencies;

Figure 6 - shows a possible digital output taken from the intensity graph of figure 5 after analogue to digital conversion;

Figure 7 - of the drawing is a block diagram in which the sub-stages of stage 2 and stage 3 are shows;

Figure 8 - of the drawing is a block diagram of the first specific embodiment;

Figure 9 - of the drawing shows the first specific embodiment;

Figure 10 - of the drawing is a block diagram of the second specific embodiment of the device;

Figure 11 - of the drawing is a block diagram of the third specific embodiment of the device;

Figure 12 - is a block diagram of a portable version of the device.

The general description of the device is as shown in figure 1 of the drawing.

Electrodes attached to the head of the system user U send signals to the amplifier and filter stage 1. This is essentially similar to the electronics employed in a conventional electroencephalogram device (EEC) to pick up cerebral electrical activity from any surrounding background of electrical noise.

Stage 2 is the frequency filtering and splitting stage and it consists of a set of N filters stages. Stage 3 consists of a set of N analogue to digital converters arranged as shown in figure 7 of the drawing. Stage 4 consists of suitable buffering and isolation circuits designed to be able to output the information sent by the system user through a suitable computer interface. The other purposes of stage 4 are to ensure that the information output is in digital form and to effectively isolate the system user from any mains powered computer equipment.

The cerebral frequency spectrum of a normal alert adult is as shown in Figure 2. It can be seen that the relative intensity falls with increasing frequency.

This intensity variation can be compensated for at either stage 1 or stage 2 or even at stage 3 where it is achieved by altering the sensitivity of the A/D converter. However a compensated intensity output can most easily be obtained at stage 2 where the gain of each of the filter stages is increased appropriately with increasing frequency to compensate for the normal intensity decreases in the signal that occurs as the input frequency approach 50 Hz.

Stage 2 and stage 3 are shown in more detail in figure 7 of the drawing. It can be seen that the input to stage 2 is split into N filter stages F1 to FN each of which can be attached to the appropriate analogue to digital converter A/D1 to A/DN. The output from these converters is a parallel data bus N bits wide which is buffered from the computer system by stage 4.

Obviously it is also possible to multiplex the inputs to stage 3 of the device so that less than N analogue to digital converters are required and either to output the information from this stage serially or to multiplex it on to the databus.

Figure 2 of the drawing which is Graph 1 shows the frequency spectrum of celebral electrical activity of a normal alert adult. The horizontal axis which is linear shows frequency in hertz. The vertical axis which is logarithmic shows a measure of the intensity of each frequency. Positioning the measuring electrodes on different parts of the head can cause variations from Graph 1. Graph 1 represents a rough average taken over several readings, actual measurement are not such smooth curves.

Figure 3 of the drawing is similar to Figure 2 but the shaded areas labelled F1 to FN represented the pass bands of the active filters F1 to FN.

Figure 4 of the drawing shows the relative intensity graph as it would be if the usual fall off in intensity with increasing frequency were electronically compensated for by suitable amplification after the filters. The shaded areas show the portions of the frequency spectrum that actually would be selected and passed by the active filters and then amplified.

Figure 5 of the drawing shows the effect of the system user deliverately varying the relative intensity of some brain wave frequencies. In this example six filters labelled F1 to F6 are used and are shaded in the manners of figure 2 and figure 3. The graph of intensity shows peaks caused by the system user at F1, F3 and F5. Figure 6 shows one possible output of the intensity graph of figure 5 after analogue to digital conversion.

Channels on the digital data bus corresponding to F1, F3 and F5 are at a level equivelant to digital logic 'high'. Channels corresponding to F2, F4 and F6 are at logic low. This could give a message or six bit code 101010. A six bit code can have $2^6 = 64$ possible different meanings; which is enough for twenty six letters, ten numbers and various punctuation and control symbols.

The principal requirements of the filters are that each particular filter stage Fi, be of a sufficiently sharp pass bank to clearly distinguish it from filters Fi-1 and Fi+1, and that the filter stages F1 to FN be tuned to frequencies spaced sufficiently far apart for the system user to be able to send meaningful signals through these filter stages without actually putting signals intended for frequency channel Fi into channels Fi-1 or Fi+1.

If six frequencies are used and can be controlled by the system user then it is possible to output $2^6 = 64$ different signals to the computer. This allows all 26 letters of the alphabet, the numbers 0 to 9, plus spacing, punctuation and control commands to be used. It also allows the allophones or phonemes in a speech synthesis system to be selected.

If five frequencies are used and can be controlled by the system user then it is possible to output $2^5 = 32$ different signals to the computer. This does not allow a full alphanumeric output but this could still give a useful output if a reduced alphabet set were used such as interchanging G for J, C for K, S for Z, spelling out Q, X and Y, and using suitable controlling software. Obviously other letters could be altered instead of these particular choices.

If less than five frequencies are used it is still possible to output a variety of signals to the computer but useful operation become more dependant on software, particurly menu driven software. It is also possible to use the computer in these situations to control other devices external to the computer. In particular any number of inputs, including only one input, can be used to control a suitable keyboard emulator.

It is possible to output information to the interface in two ways, either at two levels high or low over N frequencies giveing 2^N possible outputs to the computer or at Y distinguished levels where Y is an integer. Then it is possible to give Y^N different outputs to the computer over N frequencies.

In the case of 4 frequencies F1 to F4 which are read at 3 levels this give $4^3 = 64$ different outputs. This requires that the analogue to digital conversion stage is able to accurately distinguish all these different stages, and that they can be easily altered by the system user.

No specific claims regarding particular items of electronic circuitry are intended as the circuit blocks can be built in several different ways by any competent electronic engineer. The intention in showing specific circuit blocks is to demonstrate the viability of constructing such a device and expand on the details of its operation and usage.

By way of example the First Specific Embodiment of the device will now be discussed.

The First Specific Embodiment of the device described the operation of the prototype constructed to explore the feasability of the idea. It is a system based on monitoring 8 frequencies. All frequencies used were between 10 Hz and 50 Hz. High Q filters were required to adequately distinguish these frequencies. Q is here used here in the conventional electronic sense of meaning that the higher the Q of a bandpass filter then the narrower the bandpass about the central frequency of the filter. So the First Specific Embodiment is of the form shown in figure 8 of the drawing.

U is the system user to whom sensors are attached. The amplification and filtering stage 1 is where the small electrical signals associated with alpha and beta wave activities in the brain are amplified and filtered to remove unwanted signals and noise.

Figure 7 shows the connection between stage 1 and stage 2.

In Figure 8 of the drawing F1 to F8 comprise the frequency splitting stage. AMP1 to AMP8 comprise the amplifiers that could be used to even out any differences in analogue signal level. A/D1 to A/D8 make up the analogue to digital conversion stage. Obviously it would also be possible to multiplex the outputs from the frequency splitting or amplifier stages and thereby only need to use one fact A/D converter.

The First Specific Embodiment is also as shown in Figure 9 of the drawing. The electrical output from sensors S attached to the system user U were fed into the brain wave controlled computer interface W. The signals were passed through the amplifying and filtering stage 1, the filter stage 2, the analogue to digital conversion stage 3 and the buffer and isolation stage 4. All of these stagesd 1, 2, 3 and 4 are subunits of W. Outputs from W were fed into a computer C and displayed on a display system V.

The controlling software program was set to allow any character repeated 3 times to be stored on the screen. No claims herein are made with respect to the software of the system and any reference to the very flexible software of the system is purely intended to help explain the hardware operation of the device.

One problem is the presence of false signals caused by non-neurological electrical activities, such as movement of the muscles controlling the eyes or eyebrows, or any other muscles near the electrodes. However, this type of electrical activity can effect all the N frequency channels almost simultaneously and can be compensated for.

Another error effect is caused by the slight movement of the electrodes. Both of these error effects can cause all the N frequency channels to all go high or all go low almost simultaneously and so logic can be used to moniter the data bus and disable the buffer interface should appropriate signals be detected. Initially on the prototype channels 1 and 8 which were not being used for communication were used for error monitoring.

Equally it is obvious that suitable software can be devised that simply ignores most obvious error signals.

Second Specific Embodiment. It is also possible to construct a brain wave controlled interface device with its own on-board computer or microprocessor controlled system rather than connect an interface device to an external computer. This is discussed as the Second Specific Embodiment of the device.

It is possible to display information from the interface device on its own on-board display system and this information can then be sent out to other devices. A block diagram of this specific embodiment is shown in Figure 10 of the drawing.

Here 1 is the usual input stage found in such devices, 2 is the filter stage, 3 is the analogue to digital conversion stage, M is the on-board computer stage and D is the on-board display system.

Third Specific Embodiment. It is also possible to construct a version of this type of device that is not physically connected from one stage to another. That is to say the information sent out by the system user is transmitted between one stage of the device itself and another stage, or between the device and whatever computer or other machine to which it is interfaced, by means of suitable transmitter and receiver stages incorporated into the Brain Wave Controlled Computer Interface and any other device with which it is in communication.

Figure 11 of the drawing shows a block diagram of one version of this device where 1 is the analogue input stage, 2 is the filter stage, 3 is the analogue to digital conversion stages, 4 is the buffer stage, and T is the transmitter stage. The transmitter stage encodes the digital information in a suitable form for transmission and then transmits the information by a suitable means, such as by electromagnetic waves or by sound. If necessary the receiver R receives and decodes the information and then sends it to a computer C or other suitable device.

Fourth Specific Embodiment of the Device.

It is also possible to include all the relevant stages shown in figure 11 in a portable device worn by the system user.

Figure 12 is a block diagram of such a device. C is a portable computer system carried by the system user. T is a portable transmitter stage. P is a portable personal display system stage whereby the system user can check information before transmitting. The stage P could contain a "head-up display" device, or a portable display device of any other kind, or an audible information system allowing the system user to hear the message before transmitting it.

All parts of this system could be worn internally by the system user.

CLAIMS

1. A Brain Wave Controlled Computer Interface comprising amplifier and filtering stages, frequency splitting and filtering stages, and analogue to digital conversion stages.

2. A Brain Wave Controlled Computer Interface as claimed Claim 1 comprising amplifier and filtering stages, frequency splitting and filtering stages, and analogue to digital conversion stages, and buffering stages.

3. A Brain Wave Controlled Computer Interface as claimed in Claim 1 or Claim 2 as described in the First Specific Embodiment of the device.

4. A Brain Wave Controlled Computer Interface as claimed in Claim 1 or Claim 2 or Claim 3 as described in the Second Specific Embodiment of the device wherein the device contains its own on-board computer or microprocessor based system.

5. A Brain Wave Controlled Computer Interface as claimed in any previous claim as described in the Third Specific Embodiment of the device wherein there is a transmission link included as part of the system allowing part of the system or the whole system to be carried about or worn while being used by the system user.

6. A Brain Wave Controlled Computer Interface as claimed in any previous claim as described in the Fourth Specific Embodiment of the device where in it is also possible to include all the relevant stages in a portable device worn by the system user.

7. A Brain Wave Controlled Computer Interface device substantially as described herein with reference to figures 1-12 of the accompanying drawings.

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